PATENT

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ASSISTED HYDRAULIC SYSTEM FOR MOVING A STRUCTURAL MEMBER

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a fragmentary side view of one version of the system having a hydraulic circuit assisted by an assist cylinder connected between two structural members;

Figure 2 is a fragmentary side view of an assist cylinder according to one version of the present invention;

Figure 3 is a cross-sectional view of another version of an assist cylinder according to the present invention;

Figure 4 is a plan view of one version of a hydraulic circuit that may be employed by the system;

Figure 5 is a diagrammatic view of a version of an assist cylinder comprising an auxiliary expansion tank and a circuit connecting the assist cylinder to the tank;

Figure 6 is a side view of one version of a system employed by an excavator machine;

Figure 7 is a diagrammatic fragmentary side view of still another version of the hydraulic circuit of the invention showing the boom in an elevated position; and

Figure 8 is a diagrammatic fragmentary side view of the version of Fig. 7 showing the boom in the lowered position.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Although the disclosure hereof is detailed and exact in order to enable those skilled in the art to practice the invention, the various versions herein disclosed merely exemplify the invention which may be embodied in other specific structure. The scope of the invention is defined in the claims appended hereto.

A system **10** is provided in the versions of the present invention in which a hydraulic circuit **12** having a hydraulic cylinder **14** connected between two structural members **16** is employed to move one of the structural members relative to the other, an assist cylinder **18** being additionally employed to capture potential energy when the one structural member is moved from a relatively greater potential energy position to a relatively lower or zero potential energy position. The captured potential energy is then converted to kinetic energy that is used to generate a force exerted through the assist cylinder that assists the hydraulic circuit in the return of the one structural member toward the position of greater potential energy.

One contextual example of the use of the system is a boom **20** pivotally connected to a support **22** for raising and lowering the boom 20 about the pivot point **24**. When in a raised position, the boom **20** has a greater potential energy

than when in a lowered position. When moved from the raised position to the lowered position by the hydraulic circuit **12**, the potential energy difference ordinarily lost is captured by the assist cylinder **18** of the system **10** and converted to kinetic energy when the hydraulic circuit is controlled to again raise the boom. The assist cylinder is configured to channel the kinetic energy into an assisting force that lifts the boom toward the raised position, thus both speeding up the raising of the boom 20 and allowing smaller and less expensive components to be utilized.

The scope of the disclosure and the attached claims includes any use of a hydraulic circuit to move one member relative to another from a position of greater potential energy to a position of lower potential energy, combined with the use of an assist cylinder to capture the potential energy and convert it to kinetic energy to assist additional movement of the member with less additional energy used by the hydraulic circuit. The system having a boom **20** pivotally connected to a boom support **22** is for illustrative purposes only. Examples of such systems include excavators, backhoes, and cranes. Aspects of an excavator using the system are generally shown in the drawings.

As shown in the drawings, a system **10** for hydraulically raising and lowering a boom **20** that is pivotally connected at one end to a boom support **22** comprises a hydraulic circuit **12** connected to the boom and boom support and an assist cylinder **18** connected between the boom **20** and boom support **22**. The hydraulic circuit **12** is configured to controllably raise and lower the boom **20**

relative to the boom support **22**. The assist cylinder **18** has first and second ends **26**, **28** pivotally secured to the boom **20** and the boom support **22**, respectively. In one version, the assist cylinder **18** comprises a hollow interior **30** that contains a compressible medium **32**. In other versions, the compressible medium **32** comprises any suitable compressible gas, such as nitrogen, air and oxygen containing gases are less preferred because of their explosive possibilities.

As shown in Figure 2, in one version the assist cylinder **18** comprises a piston **34** that is moveable within the interior **30** and sealably mounted therein about the periphery **36** of the piston. In other versions, the assist cylinder **18** further comprises a rod **38** secured on one side **40** of the piston **34** that generally extends from the interior **30** at an exit end **42** thereof. The distal end **44** of the rod **38** comprises the first end **26** of the assist cylinder **18**. The interior **30** in yet other versions comprises a closed end **46** generally opposite the exit end **42**. In yet other versions, the second end **28** of the assist cylinder **18** is external of the closed end **46**. In yet other versions, the assist cylinder **18** comprises a typical rod-and-piston cylinder structure.

In one version, the interior **30** and the piston **34** define a dynamic chamber **48** between the closed end **46** and the piston **34**. The dynamic chamber **48** sealably contains the compressible medium **32**, which is compressed within the dynamic chamber when the rod **38** is retracted within the interior **30**. This causes the piston **34** to move toward the closed end **46**. In other versions, the rod **38** comprises a chamber **50** therein that is in fluid communication with the dynamic

chamber **48** through one or more vents **52** in the medial portion **54** of the piston. The space **56** thus defined by the dynamic chamber **48** and the chamber **50** in such embodiments sealably contains the compressible medium **32**, which is similarly compressed within that defined space when the rod **38** retracts and the piston **34** is moved closer to the closed end **46**.

When the hydraulic circuit **12** is used to lower the boom **20** from a raised position, the rod **38** is caused to retract within the interior **30** because it is pivotally connected at the first end **26** to the boom **20**. The retraction reduces the volume of the dynamic chamber **48** and correspondingly increases the pressure therein (or in the defined space **56** in embodiments also having a chamber **50** within the rod **38**). The increased pressure thereby generates a corresponding potential energy within the assist cylinder **18** that is retained throughout the time the hydraulic circuit **12** is lowering the boom **20** and/or maintaining the boom in a lowered position.

When the hydraulic cylinder **14** is used to controllably raise the boom **20**, whether a slight raise or a complete raise, the built-up pressure in the interior **30** is permitted to be relieved by expanding against the piston **34** with a force that causes the rod **38** to extend from the interior **30**, which extension correspondingly exerts a generally upward force on the boom **20** at the first end **26** of the assist cylinder **18**. See Fig. 3.

As shown in Figure 4, in one version the hydraulic circuit **12** comprises at least one hydraulic cylinder **14**, each having an upper end **58** pivotally secured to

the boom **20** and a lower end **60** pivotally secured to the boom support **22**. Hydraulic cylinders **14** are generally known in the art for use in moving one member **16** relative to another using hydraulic principles, such as in single acting and double acting hydraulic cylinders connected to a hydraulic fluid reservoir **62** via one or more hydraulic fluid pumps **64** and hydraulic lines **66** for charging and relieving one or more cylinder chambers **68** in order to force the piston **70** therein to move one way or the other, thereby causing the rod **72** secured thereto to extend or retract, correspondingly moving a member **16**, such as a boom **20**, to which the rod **72** is secured.

For purposes of illustration, in one version the hydraulic cylinder **14** comprises a chamber **68**, a piston **70** moveably mounted in the chamber **68**, and a rod **72** secured to one side **74** of the piston **70**. The rod **72** sealably extends from an exit end **76** of the chamber **68** and has a distal end **78** connected to a member **16** such as a boom **20**. The cylinder **14** also has a closed end **80** of the chamber **68** generally opposite the exit end **76**. External of the closed end **80** is the lower end **60**. In one version, the chamber **68** further comprises first and second dynamic interior portions **82**, **84** having variable volumes depending upon the position of the piston **70** within the chamber **68**. The first dynamic interior portion **82** is located between the piston **70** and the closed end **80**, and the second dynamic interior portion **84** is located between the piston **70** and the exit end **76**. The dynamic interior portions **82**, **84** each contain a volume of hydraulic fluid **86** and are in fluid communication with the hydraulic circuit **12**.

In the double acting hydraulic cylinder **14**, each of the first and second dynamic interior portions **82**, **84** are connected to a hydraulic fluid reservoir **62** with hydraulic lines **66**. The reservoir **62** in one embodiment is in fluid communication with at least one hydraulic pump **64** that is configured to selectively supply hydraulic fluid **86** from the reservoir **62** to either the first **82** or second **84** dynamic interior portion through hydraulic lines **66** connecting the pump **64** to the dynamic interior portions. Fluid **86** is selectively supplied to the first dynamic interior portion **82** in order to cause the piston **70** to move toward the exit end **76** and cause the rod **72** to extend from the chamber **68**. To retract the rod **72**, the opposite occurs – fluid **86** is supplied to the second dynamic interior portion **84**. In one version, additional hydraulic lines **66** are provided to connect the dynamic interior **82**, **84** portions directly to the hydraulic fluid reservoir **62** in order to direct fluid from the dynamic interior portion that is not being supplied the fluid from the pump **64**. This facilitates movement of the piston **70** so that the dynamic interior portion which is decreasing in volume discharges fluid **86** rather than compresses the fluid, which would require more force and energy to supply fluid to the other dynamic interior portion the volume of which is being increased.

The assist cylinder **18** in some versions may further comprise an auxiliary expansion tank **88** containing compressible medium **32** in order to control the pressure in the interior **30** when the boom **20** is in any given position. For example, when an excavator is at rest, the boom **20** thereof may be in a neutral

position at which pressure remains in the dynamic chamber **48** and/or the defined space **56**. This pressure will cause an undesired force to be applied to the boom **20** while the excavator is at rest. Thus, means for relieving the pressure and subsequently recharging the interior **30** are provided in conjunction with the expansion tank **88** in versions described herein.

In one version, a charge line **90** and a relief line **92** fluidly connect the expansion tank **88** to the interior **30**. The charge line **90** is configured to charge the interior **30** with the compressible medium **32** through a first port **94** located proximate the closed end **46**. The interior **30** may be charged to a minimum pressure as desired relative to the location of the piston **34** therein. To do so, in one version, a pump **96** is provided on the charge line **90** between the tank **88** and the first port **94**. The pump **96** is configured to controllably transfer the compressible medium **32** from the tank **88** to the interior **30** until the desired pressure is achieved. In other versions, a check valve **98** is provided on the charge line **90** between the pump **96** and first port **94** in order to permit compressible medium fluid flow through the charge line only in the direction of the first port.

The relief line **92** is configured to remove compressible medium **32** from the interior **30** back to the tank **88** when the pressure in the interior exceeds certain threshold pressures, or when desired by an operator (not shown). In one version, the relief line **92** fluidly connects the tank **88** to the interior **30** through a second port **100** located proximate the closed end **46**. In other versions, a relief

valve **102** is provided on the relief line **92** between the tank **88** and the second port **100**. The relief valve **102** may be configured to open and allow compressible medium **32** to exit from the second port **100** either when the interior **30** reaches the threshold pressure or when controllably and/or manually caused to do so by an operator. See Fig. 5.

In one version of an assist cylinder **18**, the interior **30** comprises an inner diameter of between about 5 inches and about 11½ inches. In other versions, the inner diameter is about 10 inches. In yet other versions, the inner diameter is about 6½ inches.

In one version of a rod **38** of an assist cylinder **18** having a chamber **50** therein, the chamber comprises an inner diameter between about 2 inches and about 6 inches. In other versions, the inner diameter of the chamber is about 4½ inches.

The stroke of the assist cylinder **18** should be compatibly configured with respect to the stroke of the hydraulic cylinder **14** in the hydraulic circuit **12**. In one version, the stroke of the assist cylinder **18** from full retraction to full extension is never realized because the stroke of the hydraulic cylinder **18** is fully extended or fully retracted prior to the full retraction and full extension of the assist cylinder, during operation. In other versions, the stroke of the assist cylinder is between 35 inches and 70 inches. In yet other embodiments, the stroke of the assist cylinder is about 49 inches.

In one version, the first and second ends **26**, **28** of the assist cylinder **18** and/or the upper and lower ends **58**, **60** of a hydraulic cylinder **14** in the hydraulic circuit **12** comprise eyes **104** that pivotally secure these ends to the boom **20** and boom support **22**. In other versions, each eye **104** comprises a bearing **106**. In yet other versions, each bearing **106** is configured to receive a pin **108** from the boom **20** or boom support **22** that is sized between about 2 inches and about 6 inches in diameter.

The amount of pressure built up in the interior **30** as a result of the retraction of the assist rod **38** caused by the lowering of the boom **20** by the hydraulic circuit **12** should be sufficient to assist raising the boom and requiring less expense of additional energy by the hydraulic circuit in doing so. In one embodiment, the maximum amount of potential energy generated in the assist cylinder **18** is convertible to kinetic energy used to exert a force on the boom **20** through the assist cylinder measuring between about 20,000 lb_f of force and 70,000 lb_f of force.

In still another version of the invention **110**, boom assist mechanism **114** includes a hydraulic cylinder **140**, disposed between the boom and the frame of the excavator and in accumulator **142** for assisting cylinder **140**. Cylinder **140** is connected between the boom **112** and the main body of the boom support structure, and is located to work cooperatively with the primary boom lift cylinder **140** raising and lower the boom.

A movable wall **144** such as a piston shown in Figs. 7 and 8 is disposed in the accumulator **142** and separates the interior of the accumulator in to first and second chambers **146**, **148** respectively, which vary in length and therefore in volume with changes in the positions of the moveable wall **144**.

A hydraulic line **150** is disposed between cylinder **140** and chamber **146** of the accumulator **142**, placing the chamber **146** and the cylinder **140** in flow communication. A hydraulic line **52** is connected between line **150** and a hydraulic fluid storage tank **154** which in most circumstances can be the existing hydraulic fluid reservoir which supplies hydraulic fluid to the other hydraulically operated devices utilized with the boom **20**. Thus, the present boom assist mechanism is an add-on device, functioning from the existing hydraulic circuitry. Line **152** should be connected to storage tank **154** below the minimum operated fluid level of the reservoir so that an uninterrupted fluid supply is available for assist cylinder **140** and accumulator **142**. Line **152** contains a check valve **156** permitting the fluid flow from the tank to line **150** if the differential pressure between the upstream and downstream pressures is great enough to open the check valve. Return line **158** having a relief valve **160** is disposed therein and extends between locations on opposite sides of the check valve **156** to pass the check valve **156** for return flow to tank **154** if line **150** becomes overcharged. A suitable hydraulic pressure gauge **162** may be connected to line **150** by a hydraulic line **164** such that the hydraulic pressure in line **150** and cylinder **140** can be monitored. Hydraulic fluid flows through line **150** between cylinder **140**

and chamber **146**. Chamber **148** contains a medium which can be compressed as the hydraulic fluid in chamber **146** moves piston **144** to the right as shown in Figs. 7 and 8. A suitable medium for use in chamber **148** is dry nitrogen or another non-explosive gas such as described above. A pressure gauge **166** may be connected to the chamber **148** of accumulator **142** by pressure line **168** for monitoring the gas pressure in the accumulator. A hydraulic line **170** connects line **50** the existing hydraulic line between pump **123** and the hoist valve and contains a shutoff valve **172**.

The use and operation of the boom assist mechanism of the present invention, the assist cylinder **18, 40** is attached to the machine between the boom and the frame of the machine. The exact location, diameter and stroke of the assist cylinder **14**, **40** must be selected to cooperate with the pressure and capacity of the accumulator **142**, to maintain proper and consistent assistance in lifting the boom. Hence, the size, location and stroke of both the cylinder **140** and accumulator **142** will vary depending upon the application of the present invention. Further, the location of the assist cylinder **142** must be selected to operate cooperatively with the primary boom lift cylinder **14**. It is advantageous in some applications to provide a plurality of boom assist cylinders **18**, **140** and accumulators **142** for more efficient operation of the assist mechanism of the invention. Hydraulic line **152** is connected to tank **154** below minimum fluid operating level of the tank, and hydraulic fluid is applied from tank **154** to cylinder **140**, hydraulic line **150** in chamber **146** principally from pump **123**

through line **170**. Chamber **148** is pre-charged with suitable quantity of gas so that, as the boom is moved for any position of the boom **20** lower than its maximum elevation, the gas in the chamber **148** exerts supplemental lifting force to the boom. For safety purposes it is desirable to release the pressure from the present mechanism when the mechanism is not in use, shutoff valve is provided. With shutoff valve **172** open, the pressure in the cylinder **140**, line **150** and chamber **146** may be relieved to tank **154** through line **170**. Pressure in chamber **148** is decreased to the to the pre-charge pressure in that piston **144** moves to the left as shown in Figs. 7 and 8 under pressure from the gas.

When the boom is to be used, shutoff valve **172** is opened and the pressure in line **150** is quickly restored by the hydraulic system of the machine when operation of the boom commences. When the boom is raised for the first time, the elevation of the boom **20** will be performed principally by the hydraulic system of the machine. The shaft of cylinder **140** will extend increasingly outwardly from the cylinder **140** as the boom **20** is raised; however, the pressure with which the chamber **148** is charged will maintain piston **144** in a position so that chamber **146** is relatively small and chamber **148** is relatively large. Valve **172** is left open and pump **23** operates until the hydraulic pressure in line **150** is substantially the same as the pre-charged pressure in chamber **148**. Valve **172** is then closed. When the boom is lowered as shown in Fig. 8, the shaft of assist cylinder **140** is moved into the cylinder and hydraulic fluid flows from the cylinder to chamber **146** of the accumulator **142**. Piston **144** is moved in the

direction of the gas containing chamber **148** thereby decreasing the size of chamber **148** and further compressing the gas therein.

The pressure in the assist system is not sufficient to raise the boom alone; however, the lift exerted on the boom **20** through the cylinder **140** by the pressurized gas reduces the effort required from the primary lift cylinders **140** to raise the boom **20**. When the primary boom cylinder **140** is operated to raise the boom **20**, the compressed gas assists the primary cylinder **140** in raising the boom **20**. The gas compressed in chamber **148** and urges piston **144** to the left as shown in Fig. 8 which has the effect of urging boom **20** upwardly through the operation of assist cylinder **140**. Thus much of the energy required for raising the boom **20** is supplied by the pressurized gas, and pressurization of the gas requires no additional energy expenditure, in that the compressed gas is further compressed by the heretofore waste of kinetic energy expended when the boom **20** is lowered. Lowering of the boom **20** moves the piston **144**, thereby compressing the gas which then exits the primary cylinder **14** when the boom is again raised.

The potential energy present in the elevated mass is converted to kinetic energy when the boom **20** is lowered, but is particularly recaptured by the present mechanism as potential energy stored in the compressed gas of assist cylinder **140**. The total energy required to raise the boom **20** remains the same with or without the present mechanism. However, when the boom assist mechanism is used, part of the total energy required to raise the boom is supplied from the compressed gas of the assist cylinder **140**. Thus, the energy put into the system

during the previous lift cycle is used to further compress the gas when the boom **20** is lowered. Hence of the total energy required to raise the boom in the next cycle part is supplied by the previous lift cycle which is captured by the compressed gas in assist cylinder **140**. In effect, the present mechanism reduces the counteracting pressure exerted by the loaded boom **20** on the primary hydraulic cylinder **140**, since the gas is compressed by the kinetic energy expended when the boom **20** is lowered.

If the boom **20** is raised while the valve **172** is closed after the hydraulic pressure has been relieved, check valve **156** will open and make up fluid will flow from tank **154**. If line **150**, cylinder **140** and chamber **146** have become over pressurized, relief valve **160** will open to relieve some fluid to the tank. Hence line **152** and **158** and valves **156** and **160** are provided for safety purposes.

As a result of the assistance provided the present mechanism various components like the engine operating the pump, the primary hydraulic cylinders **14** are operated less than maximum output and may be provided in smaller capacities resulting in substantial cost savings and fuel consumption. Assist is provided by the present boom assist mechanism enables the boom **20** to be raised more quickly thus reducing the time required for each cycle of boom operation and increasing the productivity of the boom.

While several embodiments have been disclosed herein, it is to be understood that the embodiments and variations shown and described are merely illustrative of the principles of the invention and that various modifications may

be implemented by those skilled in the art without departing from the scope and spirit of the invention and the claims appended hereto: